JAPAN

EDICT OF GOVERNMENT

JIS B 9704-1 (2000) (English): Safety of machinery -- Electro sensitive protective equipment -- Part 1: General requirements and tests

The citizens of a nation must honor the laws of the land.

Fukuzawa Yukichi

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JIS

JAPANESE
INDUSTRIAL
STANDARD

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JIS B 9704-1 : 2000

(IEC 61496-1 : 1997)

Safety of machinery—Electro-sensitive protective equipment—Part 1 : General requirements and tests

ICS 13.110; 29.260.99

Descriptors : accident prevention, emergency measures, safety devices, equipment safety, detectors

Reference number : **JIS B 9704-1 : 2000 (E)**

Foreword

This translation has been made based on the original Japanese Industrial Standard established by the Minister of International Trade and Industry through deliberations at the Japanese Industrial Standards Committee in accordance with the Industrial Standardization Law:

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In the event of any doubts arising as to the contents,
the original JIS is to be the final authority.

Contents

Safety of machinery—Electro-sensitive protective equipment— Part 1 : General requirements and tests

Introduction This Japanese Industrial Standard has been prepared based on the first edition of **IEC 61496-1** *Safety of machinery—Electro-sensitive protective equipment—Part 1 : General requirements and tests* published in 1997 with some modifications of the technical contents. Portions underlined with dots are the matters modified from the original International Standard. A list of modifications with the explanations is given in annex 1. Provision of **4.2.3.1** defines the specifications of the relevant **JIS**, as well as the specifications of the original International Standard.

A part of foreword of the original International Standard is included in introduction of this part of **JIS B 9704**, and annex C (information), which does not constitute the provisions, is excluded.

An electro-sensitive protective equipment (ESPE) is applied to machinery presenting a risk of personal injury. It provides protection by causing the machine to revert to a safe condition before a person can be placed in a hazardous situation.

This part of **JIS B 9704** provides general design and performance requirements of ESPEs for use over a broad range of appliances. Essential features of equipment meeting the requirements of this Standard are the appropriate level of safety-related performance provided and the built-in periodic functional checks/self-checks that are specified to ensure that this level of performance is maintained.

This Standard has been developed to meet the needs of manufacturers, industrial users and safety enforcement authorities. This Standard has the status of a type B standard (group safety standard) and may be used as a normative reference in a dedicated product standard for the safety of machinery.

Annexes A and B form an integral part of this Standard. Each type of machine presents its own particular hazards and it is not the purpose of this Standard to recommend the manner of application of the ESPE to any particular machine. The application of the ESPE should be a matter for agreement between the equipment supplier, the machine user and the enforcing authority, and in this context attention is drawn to the relevant guidance established internationally, for example **TR B 0008** (**ISO/TR 12100-1**) and **TR B 0009** (**ISO/TR 12100-2**).

1 Scope This part of **JIS B 9704** specifies general requirements for the design, construction and testing of electro-sensitive protective equipment (ESPE) for the safeguarding of machinery. Special attention is directed to functional and design requirements that ensure an appropriate safety-related performance is achieved. An ESPE may include optional safety-related functions, the requirements for which are given in annex A.

The particular requirements for specific types of sensing function are given in other parts of this Standard.

This Standard does not specify the dimensions of configuration of the detection zone and its disposition in relation to hazards in any particular application, nor what

constitutes a hazardous state of any machine. It is restricted to the functioning of the ESPE and how it interfaces with the machine.

This Standard may be relevant to applications other than those for the protection of persons, for example for the protection of machinery or products from mechanical damage. In those applications additional requirements may be necessary, for example when the materials that have to be recognized by the sensing function have different properties from those of persons.

This Standard does not deal with electromagnetic compatibility (EMC) emission requirements.

This part of **JIS B 9704** provides general requirements for ESPEs of various types employing different methods of sensing. The particular requirements for specific types of sensing function will be covered in subsequent parts of this Standard. The requirements for ESPEs using active opto-electric protective devices, e.g. light curtains, are contained in part 2.

This part refers to the technical suitability of the electro-sensitive protective equipment. Its application may require the use of substances and/or test procedures that could be injurious to health unless adequate precautions were taken. Conformance with this Standard in no way absolves either the supplier or the user from statutory obligations relating to the safety and health of persons during the use of the equipment covered by this Standard.

NOTE : The International Standard corresponding to this Standard is as follows.

In addition, symbols which denote the degree of correspondence in the contents between the relevant International Standard and **JIS** are IDT (identical), MOD (modified), and NEQ (not equivalent) according to **ISO/IEC Guide 21**.

IEC 61496-1 : 1997 *Safety of machinery—Electro-sensitive protective equipment—Part 1 : General requirements and tests* (MOD)

2 Normative references The following standards contain provisions which, through reference in this part of **JIS B 9704**, constitute provisions of this part. If the indication of the year of publication (or the year of coming into effect) is given to these referred standards, only the edition of the indicated year constitutes the provision of this part but the revision and amendment made thereafter do not apply.

2.1 JIS

JIS B 9960-1 : 1999 *Safety of machinery—Electrical equipment of machines—Part 1 : General requirements*

NOTE : **IEC 60204-1** : 1997 *Safety of machinery—Electrical equipment of machines—Part 1 : General requirements* is equivalent to the said standard.

JIS C 0040 : 1999 *Environmental testing Part 2 : Tests—Test Fc : Vibration (sinusoidal)*

NOTE : **IEC 60068-2-6** : 1995 *Environmental testing—Part 2 : Tests—Test Fc : Vibration (sinusoidal)* is identical with the said standard.

JIS C 0042 : 1995 *Basic environmental testing procedures Part 2 : Tests Test Eb and guidance : Bump*

NOTE : **IEC 60068-2-29** : 1987 *Environmental testing—Part 2 : Tests—Test Eb and guidance : Bump* is identical with the said standard.

JIS C 0445 : 1999 *Identification of equipment terminals and of terminations of certain designated conductors, including general rules for an alphanumeric system*

NOTE : **IEC 60445** : 1988 *Identification of equipment terminals and of terminations of certain designated conductors, including general rules for an alphanumeric system* is identical with the said standard.

JIS C 0447 : 1997 *Man-machine interface (MMI)—Actuating principles*

NOTE : **IEC 60447** : 1993 *Man-machine interface (MMI)—Actuating principles* is identical with the said standard.

JIS C 8201-5-1 : 1999 *Low-voltage switchgear and controlgear—Part 5-1 : Control circuit devices and switching elements—Electromechanical control circuit devices*

NOTE : **IEC 60947-5-1** : 1997 *Low-voltage switchgear and controlgear—Part 5-1 : Control circuit devices and switching elements—Electromechanical control circuit devices* is equivalent to the said standard.

JIS C 8480 : 1998 *Box-type switchgear assemblies for low-voltage distribution purpose,* annex 2

NOTES a) **IEC 60439-1** : 1992 *Low-voltage switchgear and controlgear assemblies—Part 1 : Type-tested and partially type-tested assemblies* is equivalent to the said annex.

b) **IEC 60664-1** : 1992 *Insulation coordination for equipment within low-voltage systems—Part 1 : Principles, requirements and tests* is equivalent to the said annex.

JIS C 0920: 1993 *Degrees of protection provided by enclosures (IP Code)*

NOTE : **IEC 60529** : 1989 *Degrees of protection provided by enclosures (IP code)* is identical with the said standard.

JIS C 1000-4-2: 1999 *Electromagnetic compatibility (EMC)—Part 4 : Testing and measurement techniques—Section 2 : Electrostatic discharge immunity test*

NOTE : **IEC 61000-4-2** : 1995 *Electromagnetic compatibility (EMC)—Part 4 : Testing and measurement techniques—Section 2 : Electrostatic discharge immunity test—Basic EMC publication* is identical with the said standard.

JIS C 1000-4-3 : 1997 *Electromagnetic compatibility (EMC)—Part 4 : Testing and measurement techniques—Section 3 : Radiated, radio-frequency, electromagnetic field immunity test*

NOTE : **IEC 61000-4-3** : 1995 *Electromagnetic compatibility (EMC)—Part 4 : Testing and measurement techniques—Section 3 : Radiated, radio-frequency, electromagnetic field immunity test—Basic EMC publication* is identical with the said standard.

JIS C 1000-4-4 : 1999 *Electromagnetic compatibility (EMC)—Part 4 : Testing and measurement techniques—Section 4 : Electrical fast transient / burst immunity test*

NOTE : **IEC 61000-4-4** : 1995 *Electromagnetic compatibility (EMC)—Part 4 : Testing and measurement techniques—Section 4 : Electrical fast transient / burst immunity test—Basic EMC publication* is equivalent to the said standard.

JIS C 1000-4-5 : 1999 *Electromagnetic compatibility (EMC)—Part 4 : Testing and measurement techniques—Section 5 : Surge immunity test*

NOTE : **IEC 61000-4-5** : 1995 *Electromagnetic compatibility (EMC)—Part 4 : Testing and measurement techniques—Section 5 : Surge immunity tests* is equivalent to the said standard.

JIS C 1000-4-6 : 1999 *Electromagnetic compatibility (EMC)—Part 4 : Testing and measurement techniques—Section 6 : Immunity to conducted disturbances, induced by radio-frequency fields*

NOTE : **IEC 61000-4-6** : 1996 *Electromagnetic compatibility (EMC)—Part 4 : Testing and measurement techniques—Section 6 : Immunity to conducted disturbances, induced by radio-frequency fields—Basic EMC publication* is equivalent to the said standard.

JIS C 6482 : 1997, **JIS C 6484** : 1997, **JIS C 6485** : 1997, **JIS C 6486** : 1996, **JIS C 6488** : 1999, **JIS C 6489** : 1999, **JIS C 6490** : 1998, **JIS C 6492** : 1998, **JIS C 6493** : 1999, **JIS C 6494** : 1999 *Copper-clad laminates for printed wiring boards*

NOTE : **IEC 60249-2** : 1985 *Base materials for printed circuits—Part 2 : Specifications* is equivalent to the said standard.

JIS C 9742 : 2000 *Isolating transformers and safety isolating transformers—Requirements*

JIS Z 9901 : 1994 *Quality systems—Model for quality assurance in design, development, production, installation and servicing*

NOTE : **ISO 9001** : 1994 *Quality systems—Model for quality assurance in design, development, production, installation and servicing* is identical with the said standard.

2.2 International standards

IEC 60050(191) : 1990 *International Electrotechnical Vocabulary (IEV)—Chapter 191 : Depend-ability and quality of service*

IEC 61310-1 : 1995 *Safety of machinery—Indication, marking and actuation—Part 1 : Requirements for visual, auditory and tactile signals*

2.3 Bibliography

TR B 0008 : 1999 *Safety of machinery—Basic concepts, general principles for design—Part 1 : Basic terminology, methodology*

NOTE : **ISO/TR 12100-1** : 1992 *Safety of machinery—Basic concepts, general principles for design—Part 1 : Basic terminology, methodology* is identical with the said technical report.

TR B 0009 : 1999 *Safety of machinery—Basic concepts, general principles for design—Part 2 : Technical principles and specifications*

NOTE : **ISO/TR 12100-2** : 1992 *Safety of machinery—Basic concepts, general principles for design—Part 2 : Technical principles and specifications* is identical with the said technical report.

3 Definitions For the purpose of this part of **JIS B 9704**, the following definitions apply.

3.1 electro-sensitive protective equipment (ESPE) An assembly of devices and/or components working together for protective tripping or presence-sensing purposes and comprising as a minimum:

— a sensing device;

— controlling/monitoring devices;

— output signal switching devices.

NOTE : The safety-related control system associated with the ESPE, or the ESPE itself, may further include a secondary switching device, muting functions, stopping performance monitor, etc. (see annex A). In order to assist in the understanding of the inter-relationship of the various major elements of the ESPE and the associated safety-related control systems, block schematic diagrams are included as figures A.1 and A.2.

3.2 controlling/monitoring device The part of the electro-sensitive protective equipment (ESPE) that:

— receives and processes information from the sensing device and provides signals to the output signal switching devices (OSSDs);

— monitors the sensing device and the OSSDs.

3.3 defined signal range The permissible signal range within which the safety-related signal threshold values have been set and are detected by the sensing device.

3.4 detection capability The sensing function parameter limit specified by the supplier that will cause actuation of the electro-sensitive protective equipment (ESPE).

3.5 detection zone The zone within which a specified test piece will be detected by the electro-sensitive protective equipment (ESPE).

3.6 external device monitoring (EDM) A means by which the electro-sensitive protective equipment (ESPE) monitors the state of control devices which are external to the ESPE.

3.7 failure The termination of the ability of an item to perform a required function. [IEV 191-04-01]

NOTE : IEV—International Electrotechnical Vocabulary

NOTES 1 After failure the item has a fault.

2 "Failure" is an event, as distinguished from "fault", which is a state.

3 This concept as defined does not apply to items consisting of software only.

4 In practice the terms fault and failure are often used synonymously.

3.8 failure to danger A failure which prevents or delays all output signal switching devices (OSSDs) going to, and/or remaining in the OFF-state in response to a condition which, in normal operation, would result in their so doing.

3.9 fault The state of an item characterized by inability to perform a required function, excluding the inability during preventive maintenance or other planned actions, or due to lack of external resources.

NOTES 1 A fault is often the result of a failure of the item itself, but may exist without prior failure.

2 In English the term "fault" and its definition are identical with those given in IEV 191-05-01.

3.10 final switching device (FSD) The component of the machine's safety-related control system that interrupts the circuit to the machine primary control element (MPCE) when the output signal switching device (OSSD) goes to the OFF-state (see figures A.1 and A.2).

3.11 integrated circuit—complex or programmable A monolithic, hybrid or module circuit, where the internal connections are not accessible, which satisfies one or more of the criteria below:

a) more than 1 000 gates are used in the digital mode;

b) more than 24 functionally different external electrical connections are available for use;

c) the functions can be programmed.

NOTES 1 Examples include ASICs, ROMs, PROMs, EPROMs, PALs, CPUs, PLAs, and PLDs.

2 The circuits may function in the analogue mode, in the digital mode, or in a combination of the two modes.

3.12 integrated circuit—simple A monolithic, hybrid or module circuit, where the internal connections are not accessible, and which satisfies none of the criteria in **3.11**.

NOTES 1 Examples are SSI or MSI logic ICs, comparators.

2 The circuits may function in the analogue mode, in the digital mode, or in a combination of the two modes.

3.13 lock-out condition A condition, initiated by a fault, preventing normal operation of the electro-sensitive protective equipment (ESPE) which is automatically

attained when all output signal switching devices (OSSDs) and, where applicable, all final switching devices (FSDs) and secondary switching devices (SSDs) are signalled to go to the OFF-state.

3.14 machine primary control element (MPCE) The electrically powered element that directly controls the normal operation of a machine in such a way that it is the last element (in time) to function when machine operation is to be initiated or arrested.

NOTE : This element can be, for example, a mains contactor, a magnetic clutch or an electrically operated hydraulic valve.

3.15 machine secondary control element (MSCE) A machine control element, independent of the machine primary control element(s), that is capable of removing the source of power from the prime mover of the relevant hazardous parts.

NOTES 1 When fitted, the MSCE is normally controlled by the secondary switching device.

2 This element can be, for example, a mains contactor, a magnetic clutch or an electrically operated hydraulic valve.

3.16 muting A temporary automatic suspension of a safety function(s) by safety-related parts of the control system.

NOTE : For ESPE-muting see **A.7**.

3.17 OFF-state The state in which the output circuit is interrupted and does not permit the flow of current.

3.18 ON-state The state in which the output circuit is complete and permits the flow of current.

3.19 output signal switching device (OSSD) The component of the electro-sensitive protective equipment (ESPE) connected to the control system of the machine which, when the sensing device is actuated during normal operation, responds by going to the OFF-state.

3.20 overall system stopping performance The time interval resulting from the sum of the electro-sensitive protective equipment (ESPE) response time and the time to the cessation of hazardous machine operation.

3.21 response time The maximum time between the occurrence of the event leading to the actuation of the sensing device and the output signal switching devices (OSSDs) achieving the OFF-state.

3.22 restart interlock A means of preventing automatic restarting of a machine after actuation of the sensing device during a hazardous part of the operating cycle of the machine, after a change in mode of operation of the machine, and after a change in the means of start control of the machine.

NOTE : Modes of operation include inch, single stroke, automatic. Means of start control include foot switch, two-hand control, and single or double actuation of the electro-sensitive protective equipment (ESPE) sensing device.

3.23 safety-related part of a control system A part or subpart(s) of a control system which respond(s) to input signals and generate(s) safety-related output signals. The combined safety-related parts of a control system start at the points where the safety-related signals are initiated and end at the output of the power control elements. This also includes monitoring systems.

3.24 secondary switching device (SSD) A device which, in a lock-out condition, performs a back-up safety function by going to the OFF-state and initiating an appropriate machine control action, e.g. de-energizing the machine secondary control element (MSCE).

3.25 sensing device That part of the electro-sensitive protective equipment (ESPE) which uses electro-sensitive means to determine the event or state that the ESPE is intended to detect, for example in an opto-electronic device the sensing function would detect an opaque object entering the detection zone.

3.26 start interlock A means which prevents an automatic machine start when the electrical supply to the electro-sensitive protective equipment (ESPE) is switched on, or is interrupted and restored.

3.27 start test A manual or automatic test which is performed after the electro-sensitive protective equipment (ESPE) has been switched on in order to test its complete safety-related control system before normal machine operation is initiated.

3.28 stopping performance monitor (SPM) A monitoring means to determine whether or not the overall system stopping performance is within the preset limit(s).

3.29 supplier An entity (e.g. manufacturer, contractor, installer, integrator) who provides equipment or services associated with the machine.

NOTE : The user may act in the capacity of a supplier to himself.

4 Functional, design and environmental requirements

4.1 Functional requirements

4.1.1 Normal operation In normal operation the ESPE shall respond by giving (an) appropriate output signal(s) when part of a person or an object enters, or is in the detection zone, or when the signal from a sensing device is within a defined signal range.

The ESPE response time shall not exceed that stated by the supplier. No means of adjustment of the response time shall be made available to the user.

4.1.2 Sensing function The sensing function shall be effective over the detection zone or the defined signal range specified by the supplier. No adjustment of the detection zone or the defined signal range shall be possible without the use of a key, key-word or tool.

4.1.3 Types of ESPE In this Standard, four types of ESPE are considered and it is the responsibility of the machine manufacturer and/or the user to prescribe which type is required for a particular application.

A type 1 ESPE shall fulfil the fault detection requirements of **4.2.2.2**.

A type 2 ESPE shall fulfil the fault detection requirements of **4.2.2.3**.

For a type 1 ESPE and for a type 2 ESPE, in normal operation the output circuit of at least one OSSD shall go to the OFF-state when the sensing device is actuated, or when power is removed from the device.

A type 3 ESPE shall fulfil the fault detection requirements of **4.2.2.4**.

A type 4 ESPE shall fulfil the fault detection requirements of **4.2.2.5**.

For a type 3 ESPE and for a type 4 ESPE, in normal operation the output circuit of at least two OSSDs shall go to the OFF-state when the sensing function is actuated, or when power is removed from the device.

4.2 Design requirements

4.2.1 Electrical supply The ESPE shall be designed to operate correctly with the conditions of the nominal supply as specified below, unless otherwise specified by the user:

AC supplies	
Voltage	0.85 to 1.1 of nominal voltage.
Frequency	0.99 to 1.01 of nominal frequency (continuously);
	0.98 to 1.02 of nominal frequency (short-time).
Harmonics	Harmonic distortion not to exceed 10 % of the total r.m.s. voltage between live conductors for the sum of the second through to the fifth harmonic. An additional 2 % of the total r.m.s. voltage between live conductors for the sum of the sixth through to the 30th harmonic is permissible.
DC supplies	
From batteries	
Voltage	0.85 to 1.15 of nominal voltage;
	0.7 to 1.2 of nominal voltage in the case of battery-operated vehicles.
From converting equipment	
Voltage	0.9 to 1.1 of nominal voltage.
Ripple (peak to peak)	Not to exceed 5 % of nominal voltage.

Any a.c. supplied ESPE or any type 4 d.c. supplied ESPE shall be provided with its own dedicated means of isolation from the supply source either by the use of an isolating transformer conforming to **JIS C 9742** or by an equivalent means of isolation.

When the ESPE incorporates a battery and is capable of being operated whilst the batteries are being charged, the charger shall incorporate an isolating transformer conforming to **JIS C 9742**.

4.2.2 Fault detection requirements

4.2.2.1 General The ESPE shall respond to the faults listed in annex B, in accordance with **4.2.2.2** to **4.2.2.5** as appropriate.

4.2.2.2 Particular requirements for a type 1 ESPE Under consideration.

4.2.2.3 Particular requirements for a type 2 ESPE A type 2 ESPE shall have a means of periodic test to reveal a failure to danger (e.g. loss of detection capability, response time exceeding that specified). The test signal shall simulate the actuation of the sensing device and the duration of the periodic test shall be as specified in the relevant part of **JIS B 9704**. Where the periodic test is intended to be initiated by an external (e.g. machine) safety-related control system, the ESPE shall be provided with suitable input facilities (e.g. terminals).

At start-up (e.g. at switch-on), the OSSD(s) shall not attain the ON-state until a periodic test has been carried out and no fault has been detected.

A single fault affecting normal operation (e.g. loss of detection capability, increase in response time) shall be detected:

— immediately; or

— as a result of the next periodic test; or

— on actuation of the sensing device,

and shall result in one of the following actions:

— initiation of a lock-out condition within the ESPE; or

— for an ESPE with only one OSSD, the generation of an initiating signal to enable an external (e.g. machine) safety-related control system to perform the lock-out function.

NOTE : A SSD may fulfil this function.

It shall not be possible for the ESPE to achieve an automatic reset from a lock-out condition by interruption and restoration of the mains power supply when the fault which initiated the lock-out condition is still present.

4.2.2.4 Particular requirements for a type 3 ESPE Under consideration.

4.2.2.5 Particular requirements for a type 4 ESPE A single fault resulting in a loss of detection capability shall cause the ESPE to go to a lock-out condition within the response time.

A single fault resulting in an increase in response time beyond the specified value or preventing one or more than one OSSD going to the OFF-state, shall cause the ESPE to go to a lock-out condition immediately, i.e. within the response time, or immediately upon any of the following demand events where fault detection requires a change of state:

— on actuation of the sensing device;

— on switch off/on;

— on reset.

It shall not be possible for the ESPE to achieve an automatic reset from a lock-out condition by interruption and restoration of the mains power supply when the fault which initiated the lock-out condition is still present.

In cases where a single fault which in itself does not cause a failure to danger is not detected, the occurrence of further faults shall not cause a failure to danger. For verification of this requirement see **5.3.5**.

NOTES 1 Design measures for a type 4 ESPE may include:

— single-channel technique with dynamic fault detection measures; or

— single-channel technique with an internally generated automatic check, performed frequently so that the automatic check interval for fault detection is included in the response time; and

— multiple channel techniques such that any disparity between channels results in a lock-out condition.

2 For additional requirements for integrated circuits, complex or programmable, see **4.2.10**.

4.2.3 Electrical equipment of the ESPE

4.2.3.1 General The electrical equipment (components) of the ESPE shall:

— conform to **JIS** standards where they exist;

— be suitable for the intended use; and

— be operated within their specified ratings.

4.2.3.2 Protection against electric shock Protection against electric shock shall be provided in accordance with **6.1** of **JIS B 9960-1**.

4.2.3.3 Protection of electrical equipment Overcurrent protection shall be provided in accordance with **7.2.1**, **7.2.3**, **7.2.7**, **7.2.8**, and **7.2.9** of **JIS B 9960-1**.

NOTE : Information may need to be given to the user of the ESPE as to the maximum rating of fuses, or setting of an overcurrent protective device for the circuit(s) connected to the OSSD(s) output connection points.

4.2.3.4 Pollution degree The electrical equipment shall be suitable for pollution degree 2 (see **6.1.2.3** of annex 2 of **JIS C 8480**).

4.2.3.5 Clearance, creepage distances and isolating distances The electrical equipment shall be designed and constructed in accordance with **7.1.2** of annex 2 of **JIS C 8480**.

4.2.3.6 Wiring The electrical equipment shall be wired in accordance with **7.8.3** of annex 2 of **JIS C 8480**.

4.2.4 Output signal switching devices (OSSDs) Separate output connections points (terminals) shall be provided for each OSSD.

The OSSDs should be so rated that their loads can be switched without the use of arc suppression devices.

In the interest of improved reliability, it is strongly recommended that switching voltage-suppression devices are fitted, which should be connected across the loads and not across the contacts.

The output circuit(s) of the OSSDs should be adequately protected to prevent failure to danger, for example welded contacts under overcurrent conditions (see **7.2.9** of **JIS B 9960-1**).

Some functions of the safety-related control system of the machine may be performed by the ESPE, for example of OSSD may perform the function of a FSD. Both a type 3 ESPE and a type 4 ESPE shall incorporate a minimum of two OSSDs.

4.2.5 Indicator lights and displays Devices shall be provided to:

a) indicate the actuation of the sensing device. Neither the time from the actuation of the sensing device to the indicator achieving 50 % of its final brightness (luminescence), nor the time from the de-actuation of the sensing device to the indicator brightness decaying to 50 % of its initial brightness, shall exceed 100 ms;

b) indicate the output status of an OSSD. The ON-state shall be represented by a green indicator, the OFF-state by a red indicator.

4.2.6 Adjustment means All adjustment means shall be so designed that a failure to danger is not possible at any point in the range of adjustment.

4.2.7 Disconnection of subsystems When means are provided to permit disconnection of any subsystem, part of a subsystem or any plug-in component, such disconnection shall result in at least one OSSD going to the OFF-state, in accordance with **4.2.2**.

4.2.8 Non-electrical components Non-electrical components shall be suitable for the intended use.

4.2.9 Common cause failures The design should be such as to minimize the possibility of a failure to danger from common cause failures arising from:

— environmental influences;

— multichannel systems using a common substrate;

— short circuits between channels of multichannel systems.

NOTE : Common cause failure can also result from the use of components degraded by mishandling, faulty manufacture, etc.

None of the components in a common semi-conductor substrate shall be used for more than one channel of a multichannel system.

4.2.10 Programmable or complex integrated circuits Where programmable or complex integrated circuits are used in a type 4 ESPE, the safety-related performance shall be maintained by two independent controlling/monitoring channels. This requirement shall be verified in accordance with **5.5**.

4.2.11 Software, programming, functional design of integrated circuits

4.2.11.1 General Where an ESPE implements its safety-related performance by any of the following means, the additional requirements of **4.2.11.2** shall apply:

a) a software program(s) executed during operation;

b) a programmed device(s), the functions of which were set by a process subsequent to its original manufacture, e.g. PAL, PLA, PLD, PROM;

c) a device(s) manufactured to a specific user functional specification, e.g. ASIC, mask programmed microprocessor, ROM.

Conformance to these requirements shall be validated in accordance with **5.5**.

4.2.11.2 Requirements

a) The software, device program and device function design shall be developed within a quality management system that meets the requirements of **JIS Z 9901**.

b) Documentary evidence shall be available under the quality management system procedures to demonstrate that the required level of safety-related performance has been achieved.

c) Prior to any development, the conceptual design of the ESPE shall be analysed for the identification of hazards and failure modes, in order to identify, in a safety requirements specification, the ESPE safety-related functions. Some or all of the ESPE safety-related functions shall then be allocated to the means in **4.2.11**, and the required safety-related performance for each element shall be determined. Suitable engineering techniques for specification, design, implementation and maintenance shall be adopted to achieve the required safety-related performance.

d) A documented quality plan, clearly identifying the stages of development, and setting out the acceptance criteria for each stage, shall be produced. Examples of development stages are requirements specification, design specification, verification, and validation.

e) The requirements for software, program design, and functional design, for each part relevant to **4.2.11.1** shall be complete and unambiguous. Each requirements specification shall enable an assessor or validator (i.e. a person other than the designer) to trace back readily to the safety requirements specification to confirm that the required safety-related functions are adequately addressed.

f) A comprehensive test plan shall be devised in order to demonstrate that the working design is a correct implementation of the safety-related functions required by the safety requirements specification. The test of software, program, and functional specification, shall be documented in the project records as evidence that the design satisfies the safety requirements specification.

g) The software, program design, and functional specification design, shall be subject to effective configuration management and change control. During development, effective procedures shall confirm that changes in requirements, specification, design, etc. are adequately documented and that the impact of all changes is analysed to confirm that the safety requirements specification remains traceable through to the working design. The working design shall be protected from unauthorized change, and its precise configuration (e.g. list of modules, version number) shall be recorded accurately.

h) Where a software program is executed during operation of the ESPE, the entire operational instruction software shall be contained in read-only memory which cannot be overwritten by the processor. Appropriate techniques shall be included to monitor correct program flow, and to confirm the integrity of the software. Such techniques can include a watchdog, RAM/ROM checks, CPU test, etc.

i) Where software tools such as compilers or translators (but not assemblers) are used to develop software, software diversity shall not be considered to be present unless:

   — the software tools used for the diverse programs are entirely unrelated; or

   — the test plan incorporates adequate measures to detect common cause errors introduced by the software tool.

j) As a principle of design, the safety-related software shall be isolated, as far as is practicable, from non-safety-related software in order to minimize the possibility of corruption of the safety functions, and to assist the task of assessing the safety performance.

4.3 Environmental requirements

4.3.1 Ambient air temperature range and humidity The ESPE shall comply with the requirements of this Standard when subjected to ambient temperature variations from 0 °C to 50 °C. Where it is intended for use outside this range, the supplier shall specify the temperature range over which the system will continue in normal operation. Compliance with this requirement shall be verified by the tests specified in **5.4.2** at a non-condensing humidity of 95 % for temperatures between 20 °C and the highest ambient temperature according to **5.4.2**.

4.3.2 Electrical disturbances

4.3.2.1 Supply voltage variations The ESPE shall not fail to danger when the external supply voltage is reduced steadily and continuously from the nominal voltage to zero voltage, over a period of 10 s to 20 s, and then increased in a similar manner from zero voltage to the nominal voltage.

The ESPE shall not fail to danger when each internally derived supply voltage, in turn, is varied steadily and continuously over a period of 10 s to 20 s, from nominal voltage to zero voltage, and then increased in a similar manner from zero voltage to nominal voltage.

4.3.2.2 Supply voltage interruptions When supply voltage interruptions (dips) are applied as follows:

Test number	Dip value of rated voltage %	Dip time Ms	Dip repetition rate Hz
1)	100	10	10
2)	50	20	5
3)	50	500	0.2

the ESPE shall respond to test 1) and to test 2) by continuing in normal operation, and to test 3) by not failing to danger.

4.3.2.3 Fast transient/burst

4.3.2.3.1 General requirements The ESPE shall continue in normal operation when subjected to fast transient/burst in accordance with **JIS C 1000-4-4**:

Ports for power lines for less than 50 V a.c. or d.c. Ports for signal lines etc. with a length exceeding 1 m	1 kV (peak) according to test severity level 2 of **JIS C 1000-4-4**
Ports for power lines for 50 V a.c. and above	2 kV (peak) according to test severity level 3 of **JIS C 1000-4-4**

4.3.2.3.2 Additional requirements A type 4 ESPE shall not fail to danger when subjected to fast transient/burst in accordance with **JIS C 1000-4-4**:

Ports for power lines for d.c. and for less than 50 V a.c. Ports for signal lines etc. with a length exceeding 1 m	2 kV (peak) according to test severity level 3 of **JIS C 1000-4-4**
Ports for power lines for 50 V a.c. and above	4 kV (peak) according to test severity level 4 of **JIS C 1000-4-4**

4.3.2.4 Fast transient/surge

4.3.2.4.1 General requirements The ESPE shall continue in normal operation when subjected to fast transient/surge in accordance with **JIS C 1000-4-5**:

Ports for signal lines Power ports for d.c. and for less than 50 V a.c.	1 kV (peak) common mode according to test severity level 2 of **JIS C 1000-4-5**
Ports for power lines for 50 V a.c. and above	2 kV (peak) common mode and 1 kV (peak) differential mode according to test severity level 3 of **JIS C 1000-4-5**

4.3.2.4.2 Additional requirements A type 4 ESPE shall not fail to danger when subjected to fast transient/surge in accordance with **JIS C 1000-4-5**:

Power ports for d.c. and for less than 50 V a.c. Ports for signal lines	2 kV (peak) common mode according to test severity level 3 of **JIS C 1000-4-5**
Power ports for 50 V a.c. and above	4 kV (peak) common mode and 2 kV (peak) differential mode according to test severity level 4 of **JIS C 1000-4-5**

4.3.2.5 Electromagnetic field

4.3.2.5.1 General requirements The ESPE shall continue in normal operation when subjected to an electromagnetic field in accordance with **JIS C 1000-4-3**:

10 V/m according to test severity level 3 of **JIS C 1000-4-3**

4.3.2.5.2 Additional requirements A type 4 ESPE shall not fail to danger when subjected to an electromagnetic field in accordance with **JIS C 1000-4-3**:

30 V/m according to test severity level X of **JIS C 1000-4-3**

4.3.2.6 Conducted disturbances induced by radio-frequency fields

4.3.2.6.1 General requirements The ESPE shall continue in normal operation when subjected to conducted radio-frequency disturbances in accordance with **JIS C 1000-4-6**:

Ports for signal lines etc. with a length of 1 m to 10 m	3 V (r.m.s.) according to test severity level 2 of **JIS C 1000-4-6**
Ports for signal lines with a length exceeding 10 m Power ports. Earth ports	10 V (r.m.s.) according to test severity level 3 of **JIS C 1000-4-6**

4.3.2.6.2 Additional requirements A type 4 ESPE shall not fail to danger when subjected to conducted radio-frequency disturbances in accordance with **JIS C 1000-4-6**:

Ports for signal lines etc. with a length of 1 m to 10 m	10 V (r.m.s.) according to test severity level 3 of **JIS C 1000-4-6**
Ports for signal lines with a length exceeding 10 m Power ports. Earth ports	30 V (r.m.s.) according to test severity level X of **JIS C 1000-4-6**

4.3.2.7 Electrostatic discharge

4.3.2.7.1 General requirements The ESPE shall continue in normal operation when subjected to an electrostatic discharge in accordance with **JIS C 1000-4-2**:

6 kV contact or 8 kV air discharge,
according to test severity level 3 of **JIS C 1000-4-2**

4.3.2.7.2 Additional requirements A type 4 ESPE shall not fail to danger when subjected to an electrostatic discharge in accordance with **JIS C 1000-4-2**:

8 kV contact or 15 kV air discharge,
to test severity level 4 of **JIS C 1000-4-2**

4.3.3 Mechanical environment

4.3.3.1 Vibration The ESPE shall be capable of continuing in normal operation during the vibration tests of **5.4.4.1**.

4.3.3.2 Bump The ESPE shall be capable of continuing in normal operation during the bump tests of **5.4.4.2**.

4.3.4 Enclosures The ESPE shall have its own enclosure(s).

All enclosures of the ESPE, including those mounted remotely, shall provide a degree of protection of at least IP54 (see **JIS C 0920**), when mounted as specified by the supplier. However, when mounted in a machine controlgear enclosure having a degree of protection of at least IP54, the ESPE enclosure shall have a degree of protection of at least IP20.

NOTE : Protection against mechanical damage may be achieved by:

— a suitable location;

— the use of suitable materials and form of construction providing adequate strength; or

— the use of a protective barrier.

The method of cable entry for incoming cables shall not impair the degree of protection.

Sealing compounds which adhere to the two surfaces being joined, such that the environmental protection is degraded when the joint is separated, shall not be used to seal covers which might be removed for service access.

Enclosures shall be free from sharp edges or corners capable of causing damage to cable insulation. Compliance shall be checked by inspection.

Enclosures shall provide adequate access to enable any necessary adjustments and maintenance work to be carried out safely and effectively. The covers enabling such access shall have captive fasteners

5 Testing

5.1 General

5.1.1 Type tests

5.1.1.1 Test samples In so far as it is practicable, all parts of an ESPE shall be tested together. Where this is not practicable, parts of the ESPE may be tested separately. Examples of such situations include integrated ESPEs (ESPEs integrated in, and normally not separable from machinery) in the case of environmental tests. In such cases:

— any input signals necessary for the operation of the ESPE shall be simulated;

— these exceptions and any omissions of tests shall be stated in the test report.

Where a particular test would be destructive and identical results could be obtained by testing part of ESPE in isolation, a sample of that part may be used instead of the whole equipment sample for the purpose of obtaining the results of the test.

Where the ESPE is designed for operation at a number of different supply voltages (e.g. for differing applications), more than one sample may be required.

When the ESPE is designed to be supplied from an external dedicated power supply, the ESPE shall undergo testing with the specified dedicated power supply.

5.1.1.2 Operating condition Unless otherwise sated in the test procedure, the tests shall be carried out with the test sample operating within the conditions specified in the accompanying documents.

For the purposes of electrical disturbance immunity tests, the equipment shall be in as near its final operating configuration as is possible (i.e. with all peripheral devices and covers attached, connected to the power supply and, where applicable, connected to the external protective conductor). When several mounting positions are specified, the least favourable mounting position shall be used.

5.1.2 Test conditions

5.1.2.1 Test environment Except where otherwise specified in **5.4**, the tests shall be carried out with the ESPE operated under the following conditions:

- rated voltage (or a voltage within the rated voltage range);
- rated frequency (or a frequency within the rated frequency range);
- ambient temperature: 20 °C ± 5 °C;
- relative humidity: 25 % to 75 %;
- barometric pressure: 86 kPa to 106 kPa.

NOTE : Values stated in the marking and in the accompanying documents are considered as rated values.

5.1.2.2 Measurement accuracy The errors of measurement shall not exceed:

- for measurement of ESPE response time: ± 1 ms;
- for temperature measurements: ± 3 °C;
- for electrical measurements: ± 1 %, where technically possible and/or appropriate;
- for relative humidity (RH) measurements: ± 3 % RH;
- for linear measurements: ± 1 mm or ± 1 %, whichever is the greater.

All measurements shall be made after stable temperature conditions have been achieved. This is considered to be fulfilled when the rate of temperature rise or fall is less than 2 K/h.

5.1.3 Test results The results of the tests listed in this clause shall be documented. The test results shall be arranged in a form that shows the details of each individual test and its effects. Details of any special test procedures shall be included in the test report.

5.2 Functional tests

5.2.1 Sensing function and detection capability

5.2.1.1 Sensing function The sensing function of the ESPE shall be tested as specified in the relevant part of **JIS B 9704**.

5.2.1.2 Integrity of the detection capability It shall be verified that the detection capability is maintained, or the ESPE does not fail to danger, by systematic analysis of the design employed, using tests where appropriate, as specified in the relevant part of **JIS B 9704**.

The results of the systematic analysis shall identify which tests in **5.4** require, in addition, a measurement of the response time.

5.2.2 Response time The response time shall be verified by systematic analysis and test.

The response time may be determined by electrical simulation of an actuation, provided that it includes the maximum time between the event triggering the actuation of the sensing device and the actuation.

Specific requirements for the measurement of the response time of the ESPE are given in the relevant part of **JIS B 9704**.

5.2.3 Limited functional tests

5.2.3.1 General The following limited functional tests A, B and C shall be performed to verify that under normal environmental conditions the ESPE shall continue in normal operation and that, under abnormal environmental conditions and under fault conditions, the ESPE shall not fail to danger should it not continue in normal operation.

When an ESPE is fitted with a restart interlock function, that function shall be by-passed or not selected during the performance of the tests. The restart interlock function shall be tested separately (see annex A).

5.2.3.2 Limited functional test A (A-test) With no intrusion in the detection zone or with no other defined initiation, it shall be observed, for a period of at least 5 s, unless otherwise specified, that the OSSD(s) shall be in the ON-state and shall not go to OFF-state.

5.2.3.3 Limited functional test B (B-test) With no intrusion in the detection zone or with no other defined initiation, it shall be observed, for a period of at least 5 s, unless otherwise specified, that the OSSD(s) shall be in the ON-state and shall not go to the OFF-state.

The test piece shall be brought into the detection zone or a defined initiation shall take place.

The OSSD(s) shall respond by going from the ON-state to the OFF-state within the ESPE response time. It shall be observed that, for a period of at least 5 s unless otherwise specified, the OSSD(s) remain(s) in the OFF-state with the test piece being present in the detection zone, or otherwise stay(s) actuated.

The test piece shall be removed from the detection zone or the sample shall be otherwise deactuated. The OSSD(s) shall respond by going from the OFF-state to the ON-state. It shall be observed that, for a period of at least 5 s unless otherwise

specified, the OSSD(s) remain(s) in the ON-state with the test piece not being present in the detection zone, or otherwise stay(s) physically deactuated.

5.2.3.4 Limited functional test C (C-test) This test is the same as the limited functional test B but, where the OSSD(s) should be in the ON-state, the OSSD(s) is(are) allowed to be in the OFF-state. No failure to danger shall occur. At the end of each of the relevant tests in **5.4** the ESPE shall operate normally immediately or following recovery from a lock-out condition.

5.2.4 Periodic check For a type 2 ESPE, the application of the periodic test signal to cause the OSSD(s) to go to the OFF-state shall be monitored. The total time for the test shall not exceed 150 ms.

5.2.5 Indicator lights and displays The functions and colours of indicator lights and displays shall be verified in accordance with the requirements of **4.2.5** by applying a B-test.

5.2.6 Means of adjustment The requirements of **4.1.1** and **4.1.2** shall be verified by inspection. The requirements of **4.2.6** shall be verified by inspection and by carrying out C-tests as necessary.

5.2.7 Rating of components The operation of each component within its specified ratings, throughout the entire operating range of the ESPE, shall be verified by analysis and/or inspection.

5.2.8 Output signal switching devices (OSSDs) The provision of separate output connection points (terminals) for each OSSD shall be verified by inspection.

5.3 Performance testing under fault conditions

5.3.1 General Tests for the effects of single faults selected according to **4.2.2** shall be carried out on all the relevant components of the ESPE. If further faults occur as a result of the first single fault, the first and all consequent faults shall be considered as a single fault.

In order to reduce unnecessary testing according to **5.3.2**, **5.3.3**, **5.3.4** and **5.3.5** where the results of a combination of faults can be precisely defined theoretically, an analysis statement shall be included as part of the test results statement. That statement shall be validated in accordance with **5.5.4**. In such cases, only selected (sample) tests need be carried out to confirm such analysis statements.

NOTE : In the case of complex circuit structures or components (e.g. microprocessor, complete redundancy) the review of faults is generally carried out on the structural level, i.e. based on assembled groups. See **B.1.2** for exclusion of short circuits on assembled circuit boards. See **B.1.3** and **B.1.4** for exclusion of short circuits between adjacent terminals for external connection.

5.3.2 Type 1 ESPE Under consideration.

5.3.3 Type 2 ESPE The ESPE shall be subjected to single faults to establish that a fault affecting normal operation results in a lock-out condition in accordance with **4.2.2.3**.

5.3.4 Type 3 ESPE Under consideration.

5.3.5 Type 4 ESPE The ESPE shall be subjected to single faults to establish that the fault is detected by the ESPE going to a lock-out condition and that no failure to danger occurs, in accordance with **4.2.2.5**.

When a single fault is not detected and the analysis specified in **5.3.1** cannot be carried out, the tests for the ESPE going to a lock-out condition and no failure to danger occurring shall be continued with that fault applied first and all other faults added and removed in turn. Tests shall be carried out for all undetected single faults.

When a sequence of two faults is not detected and the analysis specified in **5.3.1** cannot be carried out, the tests shall be continued for those two faults, applied in sequence, and all other single faults added and removed in turn. No failure to danger shall occur. Tests shall be carried out for all undetected double faults.

Testing for the accumulation of more than three faults need not be carried out provided that the probability of more than three faults, largely independent of each other and having to appear in a specific sequence in time, is low.

5.4 Environmental tests

5.4.1 Rated supply voltage The design measures specified in **4.2.1** shall be verified by inspection.

The ESPE shall be subjected to the following sequence of tests using the relevant values specified in **4.2.1**:

a) the ESPE shall be supplied with the lowest rated supply voltage. A B-test shall be carried out;

b) the supply voltage shall be increased, within a period of 10 s to 20 s, to the highest rated voltage, during which time an A-test shall be performed;

c) after the highest test supply voltage has been reached, a B-test shall be carried out.

The requirements for frequency variation and for harmonic distortion shall be verified either by testing or by using analytical methods.

5.4.2 Ambient temperature variation and humidity The highest ambient temperature in the tests below shall be as specified in the marking and/or the accompanying documents, but shall be not lower than +50 °C. The lowest ambient temperature in the tests below shall be as specified in the marking and/or the accompanying documents, but shall be not higher than 0 °C.

The ESPE shall be subjected to the following sequence of tests:

a) With the ESPE operating under the conditions specified in **5.1.2.1**, an A-test shall be performed with a duration of at least 2 h. At the end of that time, a B-test shall be carried out.

b) The ambient temperature shall be increased by not more than 0.3 °C per minute up to the highest ambient temperature, during which time an A-test shall be performed.

c) An A-test shall be performed with a duration of at least 2 h at the highest ambient temperature. During that time, the humidity shall be increased to 95 % and held at that value for at least 1 h. Following the A-test, a B-test shall be carried out.

d) The ambient temperature shall be decreased by not more than 0.3 °C per minute, whist maintaining the humidity at 95 %, until a temperature of 20 °C is reached, during which time an A-test shall be performed.

e) The ambient temperature shall be decreased by not more than 0.3 °C per minute, without condensation occurring, until the lowest ambient temperature is reached, during which time an A-test shall be performed.

f) An A-test shall be performed with a duration of at least 2 h at the lowest ambient temperature. At the end of that time, a B-test shall be carried out.

g) The ambient temperature shall then be increased by not more than 0.3 °C per minute to the value specified in **5.1.2.1**, during which time an A-test shall be performed.

h) An A-test shall be performed with a duration of at least 2 h at the temperature specified in **5.1.2.1**. At the end of that time a B-test shall be carried out.

5.4.3 Effects of electrical disturbances

5.4.3.1 Supply voltage variations The external supply voltage and each internally derived supply voltage shall in turn be varied in accordance with **4.3.2.1**. During each test, C-tests shall be carried out as necessary to confirm that no failure to danger occurs at reduced voltage values.

5.4.3.2 Supply voltage interruptions The tests specified in **4.3.2.2** shall be carried out with the duration of each test sufficiently long to cover at least 10 dips and to enable for each of tests 1) and 2) that a B-test shall be carried out, and for test 3) that a C-test shall be carried out.

5.4.3.3 Fast transient/burst

5.4.3.3.1 General requirements The ESPE shall be subjected to fast transient/burst to the levels specified in **4.3.2.3.1** in accordance with **JIS C 1000-4-4** (using figure 9 of **JIS C 1000-4-4** for coupling of d.c. and less than 50 V a.c power and signal ports, and figure 8 for other a.c. power ports).

During each exposure a B-test shall be carried out.

5.4.3.3.2 Additional tests A type 4 ESPE shall also be subjected to fast transient/burst of the levels specified in **4.3.2.3.2** in accordance with **JIS C 1000-4-4** (using figure 9 of **JIS C 1000-4-4** for coupling d.c. and less than 50 V a.c. power and signal ports, and figure 8 for other a.c. power ports).

During each exposure a C-test shall be carried out.

5.4.3.4 Fast transient/surge

5.4.3.4.1 General requirements The ESPE shall be subjected to fast transient/surge to the levels specified in **4.3.2.4.1** in accordance with **JIS C 1000-4-5** (using figure 10 of **JIS C 1000-4-5** for coupling of signal ports, figure 7 of **JIS C 1000-4-5** for coupling of less than 50 V a.c. and d.c. power ports, and figures 6 and 7 of **JIS C 1000-4-5** for other a.c. power ports).

During each exposure a B-test shall be carried out.

5.4.3.4.2 Additional tests The type 4 ESPE shall be subjected to fast transient/surge to the levels specified in **4.3.2.4.2** in accordance with **JIS C 1000-4-5** (using figure 10 of **JIS C 1000-4-5** for coupling of signal ports, figure 7 of **JIS C 1000-4-5** for coupling of less than 50 V a.c. and d.c. power ports, and figures 6 and 7 of **JIS C 1000-4-5** for other a.c. power ports).

During each exposure a C-test shall be carried out.

5.4.3.5 Electromagnetic field

5.4.3.5.1 General tests The ESPE shall be subjected to an electromagnetic field to the levels specified in **4.3.2.5** in accordance with **JIS C 1000-4-3**. During the exposure to severity level 3 a B-test shall be carried out.

NOTE : The result of this test is dependent on the surrounding structures which may differ from when the ESPE is fitted to a machine.

5.4.3.5.2 Additional tests A type 4 ESPE shall also be subjected to an electromagnetic field to severity level X. During the exposure a C-test shall be carried out.

NOTE : The result of this test is dependent on the surrounding structures which may differ from when the ESPE is fitted to a machine.

5.4.3.6 Conducted disturbances induced by radiofrequency fields

5.4.3.6.1 General tests The ESPE shall be subjected to conducted radiofrequency disturbances to the levels specified in **4.3.2.6.1** in accordance with **JIS C 1000-4-6**. During each exposure a B-test shall be carried out.

5.4.3.6.2 Additional tests A type 4 ESPE shall also be subjected to conducted radiofrequency disturbances to the levels specified in **4.3.2.6.2** in accordance with **JIS C 1000-4-6**. During each exposure a C-test shall be carried out.

5.4.3.7 Electrostatic discharge

5.4.3.7.1 General tests The ESPE shall be subjected to electrostatic discharge to the levels specified in **4.3.2.7.1** in accordance with **JIS C 1000-4-2**. During each exposure a B-test shall be carried out.

5.4.3.7.2 Additional tests A type 4 ESPE shall also be subjected to electrostatic discharge to the levels specified in **4.3.2.7.2** in accordance with **JIS C 1000-4-2**. During each exposure a C-test shall be carried out.

5.4.4 Mechanical influences

5.4.4.1 Vibration The test sample shall be exposed to vibration tests according to **JIS C 0040**.

The following conditions shall apply:

Frequency range	10 Hz to 55 Hz.
Sweep rate	1 octave/min.
Amplitude	0.35 mm ± 0.05 mm. The test shall be carried out without anti-vibration mountings.
Number of sweeps	20 for each axis, for three axes (no delay by resonance frequencies).

The following limited functional tests shall be performed for each axis:

— an A-test shall be performed during each of the first and last sweeps;

— a B-test shall be carried out, so that the test piece is brought into the detection zone at the beginning of the second sweep and is removed at the end of the 19th sweep.

5.4.4.2 Bump The test sample shall be exposed to bump tests according to **JIS C 0042**.

The following conditions shall apply:

Acceleration	100 m/s^2
Duration of pulse	16 ms
Number of bumps	1 000 ± 10 for each axis, for three axes

The following tests shall be performed for each axis:

— an A-test shall be performed during each of the first and last (100 ± 10) bumps;

— a B-test shall be carried out, so that the test piece is brought into the detection zone after the first (100 ± 10) bumps.

5.4.5 Enclosures The requirements of **4.3.4** for degrees of protection shall be tested in accordance with **JIS C 0920** after the tests of **5.4.4** have been completed. The remaining requirements shall be verified by inspection.

5.5 Validation of programmable or complex integrated circuits

5.5.1 General This subclause deals with the validation of the requirements of **4.2.10** and **4.2.11**, and any analysis statement included as part of the test results statement required by **5.3.1**.

Validation shall be undertaken by a competent person(s) who should be independent of those responsible for any aspect of the system design, the hardware design and the software design. A written validation report shall be compiled.

NOTE : The validation provides independent confirmation that specific requirements have been achieved. The process is intended to confirm that systematic faults in the design have been avoided, that procedures are in place to maintain safety performance during the life cycle of the product (including, for example, following modification) and that the design of the ESPE fulfils the fault detection requirements appropriate to its type.

5.5.2 Complex or programmable integrated circuits For an ESPE employing a complex or programmable integrated circuit(s), the following requirements shall be validated by analysis:

a) a minimum of two independent decision-making channels shall meet the requirements of **4.2.10**;

b) the detection of disparity between channels, and the initiation of a lock-out condition, shall be maintained under all applicable fault conditions.

5.5.3 Software, programming, functional design of integrated circuits It shall be verified that the specified procedures and supporting documentation for the quality system(s) under which the system design and software were developed meet the requirements of **JIS Z 9901**.

The operation of the quality system(s) shall be verified by an audit inspection of the documentary records pertaining to the development of the equipment and the procedures established for the maintenance of quality during the life cycle of the product.

The adequacy, completeness, and traceability of the project development documentation shall be validated by audit inspection.

The safety requirements specification shall be analysed to confirm that the requirements for software, program design, and functional design, not addressed therein have been addressed elsewhere in the system design.

The test plan shall be analysed to confirm that all the requirements of the safety requirements specification can be verified by successful completion of the tests.

When software specific to fault detection is used in operation, the test plan shall be analysed to confirm that all faults considered in **B.4.4** which cannot be tested by direct hardware fault simulation are tested by the software.

The test results of the latest issued version of the design shall be subjected to an audit inspection. Sample tests, chosen at random, shall be repeated for validation and the results shall agree in detail with those held in the project records.

When software specific to fault detection is used in operation, the test results for simulated faults shall be inspected for adequate coverage and shall be compared with any analysis statement included as part of the test results statement.

For software used in operation, it shall be verified that the entire operational instruction program is contained within read-only memory which cannot be overwritten by the processor.

For programmable devices, the means for verification that the device performs all its programmed functions shall be validated.

NOTE : Incorrectly or incompletely programmed devices may allow the equipment to perform the primary protective function correctly but fail to implement fault detection functions, particularly when multiple similar programmable devices are used within a design which depends upon cross-monitoring for fault detection.

The means employed to monitor program flow and/or the operation of complex/programmable devices shall be validated. The means shall be appropriate for the level of safety-related performance claimed by the supplier, and the system architecture employed (further guidance is under development).

5.5.4 Test results analysis statement When analysis is employed to define the result of any test required by **5.3**, the adequacy, suitability, and validity of the techniques used shall be validated. The correct implementation of the methods used shall be verified by repeating parts of the analysis selected at random.

6 Marking for identification and for safe use

6.1 General All parts of the ESPE shall bear all markings which are necessary:

— for its unambiguous identification;

— for its safe use,

and supplementary information shall be given, as appropriate:

— permanently on the ESPE;

— in accompanying documents such as instruction handbooks;

— on the packaging

Signs or written warnings only saying "danger" shall not be used. Markings, signs and written warnings shall be readily understandable and unambiguous, especially as regards the part of the function(s) of the machine which they are related to. Readily understandable signs (pictograms) should be used in preference to written warnings. Signs and pictograms should only be used if they are understood in the culture in which the machinery is to be used. Written warnings shall be drawn up in the language(s) of the country in which the machine will be used for the first time and, on request, in the language(s) understood by operators. Markings shall comply with recognized standards.

See **17.1** of **JIS B 9960-1** as regards marking of electrical equipment.

The enclosure of the most appropriate part of the ESPE shall carry the following markings:

a) identification of the product, including name and address of the supplier, designation of series or type, serial number and year of construction;

b) parameters, e.g. dimensions, of the detection zone;

c) detection capability;

d) response time;

e) rated voltage(s) including number of phases and frequency where relevant;

f) rated input power (if greater than 25 W) or rated current;

g) designation of IP code;

h) for class II equipment (see **JIS B 9960-1**) only, symbol for classification for protection against electric shock;

i) warning sign of hazards arising from dangerous voltages;

j) type of ESPE according to **4.1.3**.

6.2 ESPE supplied from a dedicated power supply Where an ESPE is designed to be supplied from an external dedicated power supply, details of the model or type of dedicated power supply with which it has been tested shall be permanently marked on the enclosure of the most appropriate part of the ESPE and included in the instructions for use.

6.3 ESPE supplied from an internal electrical power source An ESPE supplied from an internal power source shall be marked with details of the rated current of the supply fuse, if applicable, on the enclosure of the most appropriate part of the ESPE.

6.4 Adjustment When the ESPE can be adjusted to suit different rated voltages or different inputs, a marking showing the voltage or input to which the ESPE is adjusted shall be clearly and easily discernible at the point of adjustment.

6.5 Enclosures Any enclosure which contains electrical devices shall be marked with a warning sign in accordance with **17.2** of **JIS B 9960-1**.

6.6 Control devices

6.6.1 Markings for switches, indicating lamps, and other control devices shall be placed adjacent to those components; they shall not be placed on removable parts which can be replaced in such a way that the marking is misleading.

6.6.2 Functional identification of control and indicating devices shall be in accordance with **17.3** of **JIS B 9960-1**.

6.6.3 The positions of any power supply switches shall be marked according to **5.3.3** of **JIS B 9960-1**.

6.6.4 Devices intended for the adjustment of a characteristic during or after installation, shall be provided with markings of the direction of adjustment to increase or decrease the value of that characteristic. See also **JIS C 0447**.

6.7 Terminal markings

6.7.1 Terminals to which cable connections are to be made at the time of installation, or reestablished after maintenance of the ESPE, shall be marked and related to a diagram.

6.7.2 Terminals for external connections provided with, and relating to the ESPE and user replaceable components shall be marked and related to a diagram.

6.7.3 All terminals for the incoming supply connections shall be marked in accordance with **JIS C 0445**.

6.7.4 Protective conductor connection points shall be marked in accordance with **8.2.7** of **JIS B 9960-1**. This marking shall not be placed on screws, removable washers or other parts which might be removed when conductors are being connected/disconnected.

6.7.5 Where an ESPE is to be connected to more than two supply conductors it shall be provided with a connection diagram, fixed to the ESPE, unless the correct mode of connection is obvious.

6.7.6 If more than one supply is taken to an ESPE, the marking shall include a warning that all supplies have to be switched off before the terminal cover may be removed.

6.8 Marking durability Marking should be capable of withstanding the environmental influences of an industrial environment with respect to temperature and humidity as defined by this Standard, and liquids such as water, soapy water, machine oil, benzene, etc.

Markings shall be capable of withstanding being rubbed lightly for 15 s with a piece of cloth soaked with petroleum spirits, and with a piece of cloth soaked in water.

7 Accompanying documents The supplier of the ESPE shall provide documentation in the languages agreed between the user and the supplier.

The accompanying documents shall contain the information required for the installation, use and subsequent disposal of the ESPE, including the following information where applicable:

a) a statement that other devices shall not be connected to the internally generated power supplies of the ESPE;

b) details of the optional functions of the ESPE, described in annex A, which have been included and details of those optional functions that are available for future incorporation;

c) a description of facilities for connection of stopping performance monitor if provided;

d) for a type 2 ESPE, information on the means of applying an external test signal, where required (see **4.2.2**);

e) a recommendation that security keys/special tools, if provided for adjustments, operations or access, be kept under the control of a responsible or authorized person(s);

f) the size and type of the test piece and the test procedure, or description of other methods for checking the detection capability and the operation of the visual indicator;

g) the response time;

h) the rated operating conditions for the ESPE including:

— temperature range,

— humidity,

— voltage range,

— range of separation distances between the subsystems, and the maximum length of interconnecting cables.

i) advice on the prevention of mutual interference of sensing functions;

j) block diagrams, functional description chart showing sequence of relay switching operations;

k) the location of all input and output terminals;

l) the ratings and characteristics of all input/output terminals;

m) the maximum voltage and current that the output signal switching devices are capable of switching into an inductive load, and the maximum switching rate with this load;

n) information to enable the user to carry out maintenance using the supplier's recommended spares;

o) special requirements regarding input cables and terminations, if applicable;

p) the total load/power requirements of the ESPE;

q) details of the space required around the equipment for removal and maintenance purposes;

r) a list of the user-replaceable parts specified by the supplier;

s) a list of colour and coding systems (see **JIS B 9960-1**);

t) the overall dimensions of the equipment;

u) operating instructions;

v) the location and dimensions of the detection zone(s) or definitions of other functional limits, including the defined signal range;

w) a schedule of checks to be carried out after installation, after maintenance, or periodically, to establish that the device is functioning correctly;

x) the method and frequency of regular testing to confirm that the level of safety integrity is maintained;

y) a statement of the IP rating of the enclosures, or where the ESPE is intended to be mounted in a machine controlgear enclosure, the minimum IP rating required of that enclosure according to **4.3.4**;

z) a clear statement of any particular application for which the ESPE is intended;

aa) the maximum period between periodic tests for a type 2 ESPE;

bb) the installation and mounting instructions for any remote switches and controls;

cc) instructions on where parts with restart interlock should be located in relation to the danger zone;

dd) instructions on where parts with sensing functions should be located in relation to the danger zone and methods for determination of safety distances between those parts and the danger zones, for example formulae for calculation;

ee) instructions on how the ESPE should be interfaced with the machine control system;

ff) the details of any special precautions necessary to be taken into account;

gg) the dimensions of the space(s) to be provided for the ESPE;

hh) the dimensions and position of the means for supporting and fixing the ESPE within the space(s);

ii) the minimum clearances between the various parts of the ESPE and the surrounding parts of the fitment;

jj) the means of connection of the ESPE to the supply, and the interconnection of separate components, if any.

Annex A (normative)
Optional functions of the ESPE

A.1 General An ESPE may include additional functions, or devices arranged to perform functions, within the safety-related control system. The selection and utilization of such devices or functions depends on the category of control and application.

The ESPE together with the optional functions shall meet the requirements of this Standard.

NOTE : In order to assist in the understanding of an ESPE, block schematic diagrams are to be found in figures A.1 and A.2.

The following are optional devices or functions:

— external device monitoring (see **A.2**);

— stopping performance monitor (see **A.3**);

— secondary switching device (see **A.4**);

— start interlock (see **A.5**);

— restart interlock (see **A.6**);

— muting (see **A.7**);

— ESPE used as a machine reinitiation device (see **A.8**).

A.2 External device monitoring (EDM)

A.2.1 Functional requirements EDM shall provide the necessary means for the connection of signals from external devices (e.g. MPCE(s), FSD(s), muting control device) such that the EDM can unambiguously monitor the state of those devices.

The ESPE shall go to a lock-out condition when an incorrect state is detected in one of the devices being monitored by the EDM.

A.2.2 Fault condition requirements The ESPE shall respond in accordance with **4.2.2** to faults in the EDM.

A.2.3 Verification It shall be verified by inspection and test that:

— the necessary means are provided in the ESPE for the unambiguous monitoring of the devices for which the EDM is intended to be used;

— the ESPE goes to the lock-out condition when any one of the devices being monitored is in an incorrect state;

— the ESPE responds according to **4.2.2** to faults occurring in the EDM.

A.2.4 Information for use The ESPE supplier shall provide information for the connection of the EDM to the appropriate devices. The supplier shall specify the type of any device for which the EDM is intended to be used. Where the monitored devices require particular characteristics (e.g. mechanically linked contacts, duplicate inputs, N/O, N/C) these shall be specified.

A.3 Stopping performance monitor (SPM)

A.3.1 Functional requirements The SPM shall provide signals to the ESPE related to the time taken by, or the amount of travel of, the hazardous parts of the machine in coming to rest or reverting to a safe condition. The ESPE shall go to a lock-out condition when a signal(s) from the SPM indicate(s) that the preset limit of stopping performance has been exceeded.

For a type 4 ESPE, the SPM shall provide at least two signalling channels to the ESPE. Each channel shall be capable of initiating a lock-out condition of the ESPE.

The SPM shall apply an automatic stopping performance test to monitor the overall system stopping performance.

The SPM shall be capable of initiating the automatic stopping performance test in response to signals derived from the ESPE, immediately upon actual or simulated actuation of the sensing device.

Any means by which the preset limit(s) within the SPM may be adjusted shall be in a lockable enclosure.

A.3.2 Fault condition requirements The ESPE shall go to a lock-out condition in response to any of the following conditions:

— upon failure to apply, or to complete the automatic test;

— upon failure of transmission of motion to the stopping performance monitor or, when duplicated transmission means are used, upon failure of either one of those means;

— upon disconnection of the stopping performance monitor from the ESPE.

A.3.3 Verification Verify by inspection that:

— the SPM output signal(s) causes the ESPE to go to a lock-out condition when the preset limit of stopping performance is exceeded;

— for a type 4 ESPE application, there are at least two independent signal sources, from the SPM to the ESPE, and failure of either one of those causes lock-out;

— the SPM initiates an automatic test in response to a signal from the ESPE;

— the ESPE initiates an automatic SPM test upon actual or simulated actuation of the sensing function;

— any adjustment means is in a lockable enclosure;

— when the automatic test has failed to be applied or completed, a lock-out condition is achieved;

— when any of the transmission of motion means has failed, a lock-out condition is achieved;

— when a SPM is disconnected from the ESPE, or from the safety-related control system, a lock-out condition is achieved;

— the markings conform to **A.3.4** and are correct.

A.3.4 Marking The supplier shall provide permanently affixed markings to the SPM giving the following information:

— name and address of the supplier;

— the model type number and serial number;

— the ESPE type number for which the SPM is designed;

— the accuracy of the unit.

A.4 Secondary switching device (SSD)

A.4.1 Functional requirements When the ESPE power supply is switched off or when the ESPE is in a lock-out condition, the SSD shall be in the OFF-state.

The ability of the SSD to perform its safety-related function shall be checked by an automatic start test, carried out when the ESPE power supply is switched on and before the OSSD(s) go to the ON-state.

A.4.2 Fault condition requirements If the start test referred to in **A.4.1** identifies the inability of the SSD to go to the OFF-state, the OSSD(s) shall remain in the OFF-state.

A.4.3 Verification Verify by inspection and test that:

— when the SSD is in the ON-state and ESPE power supply is switched on, the OSSD(s) remain(s) in the OFF-state, even when a reset is attempted;

— the SSD is in the OFF-state under lock-out conditions.

A.5 Start interlock

A.5.1 Functional requirements The start interlock shall prevent the OSSD(s) going to the ON-state when the electrical supply is switched on, or is interrupted and restored.

The OFF-state of the OSSD(s) shall continue until the start interlock is reset to its ON-state, manually (e.g. by switch operation or by actuation and de-actuation of the sensing device).

It shall not be possible for a start interlock to reset the OSSD(s) to the ON-state under a lock-out condition.

A.5.2 Fault condition requirements A failure of the start interlock which causes it to go to, or remain in a permanent ON-state shall cause the ESPE to go to, or to remain in the lock-out condition.

A.5.3 Verification Verify by inspection and test that:

— the OSSD(s) is(are) in the OFF-state when the start interlock is in the OFF-state;

— when the power supply is switched on, the OSSD(s) remain(s) in the OFF-state until the start interlock is manually operated;

— during a lock-out condition, an attempt to reset the start interlock does not allow the OSSD(s) to go to the ON-state;

— the lock-out condition is initiated if the start interlock fails.

A.5.4 Indication A yellow indicator shall be provided which should illuminate when the OSSD(s) is(are) prevented from going to the ON-state by the start interlock.

A.6 Restart interlock

A.6.1 Functional requirements The restart interlock shall prevent the OSSD(s) going to the ON-state when:

— the detection zone is interrupted, or the defined signal range is exceeded, while the machine operation is at a hazardous part of its operating cycle;

— the detection zone is interrupted, or the defined signal range is exceeded, while the machine is in automatic or semi-automatic mode;

— there is a change of the machine operating mode or type of operation.

The interlock condition shall continue until the restart interlock is manually reset. However, it shall not be possible to reset the restart interlock whilst the sensing device is actuated or the defined signal range is exceeded.

A.6.2 Fault condition requirements A failure to meet the functional requirements of **A.6.1** shall cause the ESPE to go to the lock-out condition.

A.6.3 Verification Verify by inspection and test that:

— the OSSD(s) is in the OFF-state when the restart interlock is in the OFF-state;

— the restart interlock will not reset to the ON-state while the sensing device is actuated;

— the restart interlock goes to the OFF-state on sensing device actuation during a hazardous machine operation;

— when the machine operating mode or type of operation is changed, the restart interlock goes to the OFF-state;

— the lock-out condition is initiated if the restart interlock fails;

— resetting the restart interlock will not go to the ON-state whilst the sensing device is actuated or the defined signal range is exceeded.

A.6.4 Indication A yellow indicator shall be provided which should illuminate when the OSSD(s) is prevented from going to the ON-state by the restart interlock.

A.7 Muting

A.7.1 Functional requirements

A.7.1.1 When the ESPE is in a muted condition, the OSSD(s) shall remain in the ON-state on actuation of the sensing device.

A.7.1.2 In a type 3 ESPE and in a type 4 ESPE there shall be facilities for connecting two independent hard-wired muting signal sources.

Should conflicting muting signals occur, the ESPE shall not allow a muted condition to occur.

A.7.2 Fault condition requirements

A.7.2.1 In a type 2 ESPE, any fault in the muting input shall be revealed by the periodic test, and shall at least not allow a muted condition to occur.

A.7.2.2 Any fault condition of the mute indicator(s) which results in a failure to conform to the requirements of **A.7.4** shall not allow a muted condition to occur.

A.7.3 Verification Verify by inspection and test that:

- in a muted condition, the OSSD(s) remain(s) in the ON-state on actuation of the sensing device;
- in a type 3 ESPE and in a type 4 ESPE there are two independent hard-wired muting signal sources and a muted condition is prevented whenever an invalid combination of signals is present;
- in a type 2 ESPE, any failure which could lead to a hazardous condition is revealed by the periodic test, and when such a failure is detected, a muted condition is prevented;
- visual indicators are provided as required by **A.7.4**;
- a failure of the indicators to comply with **A.7.4** is revealed by the prevention of a muted condition.

A.7.4 Indication One or more visual indicators shall be provided which shall illuminate when the ESPE is in a muted condition in accordance with **4.2.3** of **IEC 61310-1**. The illuminated area of each muted condition indicator shall be at least 1 cm^2 and shall have a brightness (luminance) of not less than 200 cd/m^2.

NOTE : The mute indicator(s) should be arranged to be readily visible from any normal position of the operator of the machine to which the ESPE is designated to be applied, and from the position at which any adjustment of the muting is normally carried out.

A.8 ESPE used for reinitiation of machine operation

A.8.1 General If, in addition to its function as a protective device, the ESPE is to be used to initiate machine operation, the following modes of operation can be used:

- single break, where an actuation and de-actuation of the sensing device initiates machine movement;
- double break, where two consecutive actuations and de-actuations of the sensing device initiate machine movement.

Where this optional feature is provided as part of the ESPE, a start interlock as specified in **A.5**, and a restart interlock as specified in **A.6**, shall also be provided within the ESPE.

A.8.2 Functional requirements

a) When the ESPE power is switched on or is interrupted and restored, it shall not be possible to use either of the modes of operation described in **A.8.1** before the start interlock has been reset.

b) After actuation of the sensing device during hazardous motion, it shall not be possible to use either of the modes of operation described in **A.8.1** before the restart interlock has been reset.

c) Successive initiations of machine operation by the use of either of the modes of operation described in **A.8.1** shall be possible only within a limited period of time.

d) When double break initiation is selected, initiation by single break shall not be possible under any sequence of events or actions.

e) If the limited period of time referred to in **c**) is exceeded, further machine initiation shall not be possible until the restart interlock has been reset.

f) Machine initiation by either of the modes of operation described in **A.8.1** shall not be possible following a change of initiation mode until the restart interlock has been reset.

g) Facilities shall be provided to reset the timer controlling the limited period described in **c**) by external means.

h) The adjustment means for the timer shall be within an enclosure with access requiring the use of tools.

A.8.3 Fault condition requirements Any fault listed in annex B leading to a change in the machine initiation mode shall at least result in the operation of either the start interlock or the restart interlock.

A.8.4 Verification Verify by inspection and test that:

— after the ESPE power is switched on, or is interrupted and restored, it is not possible to use either of the modes of operation described in **A.8.1** until the start interlock has been reset;

— after actuation of the sensing device during hazardous motion, it is not possible to use either of the modes of operation described in **A.8.1** until the restart interlock has been reset;

— successive initiations of machine operation by the use of either of the modes of operation described in **A.8.1** shall only be possible within a limited time period;

— when double break initiation is selected, initiation by a single break shall not be possible under any sequence of events or actions;

— machine initiation by either of the modes of operation described in **A.8.1** shall not be possible following a change of initiation mode until the restart interlock has been reset;

— facilities are provided to reset the timer controlling the limited period described in **c**), by external means;

— the adjustment means for the timer are within an enclosure with access requiring the use of tools;

— faults listed in annex B leading to a change in the machine initiation mode shall at least result in operation of either the start interlock or the restart interlock.

NOTE : The time period permitted for successive initiations should not exceed 30 s for machinery having a cycle time of less than 5 s.

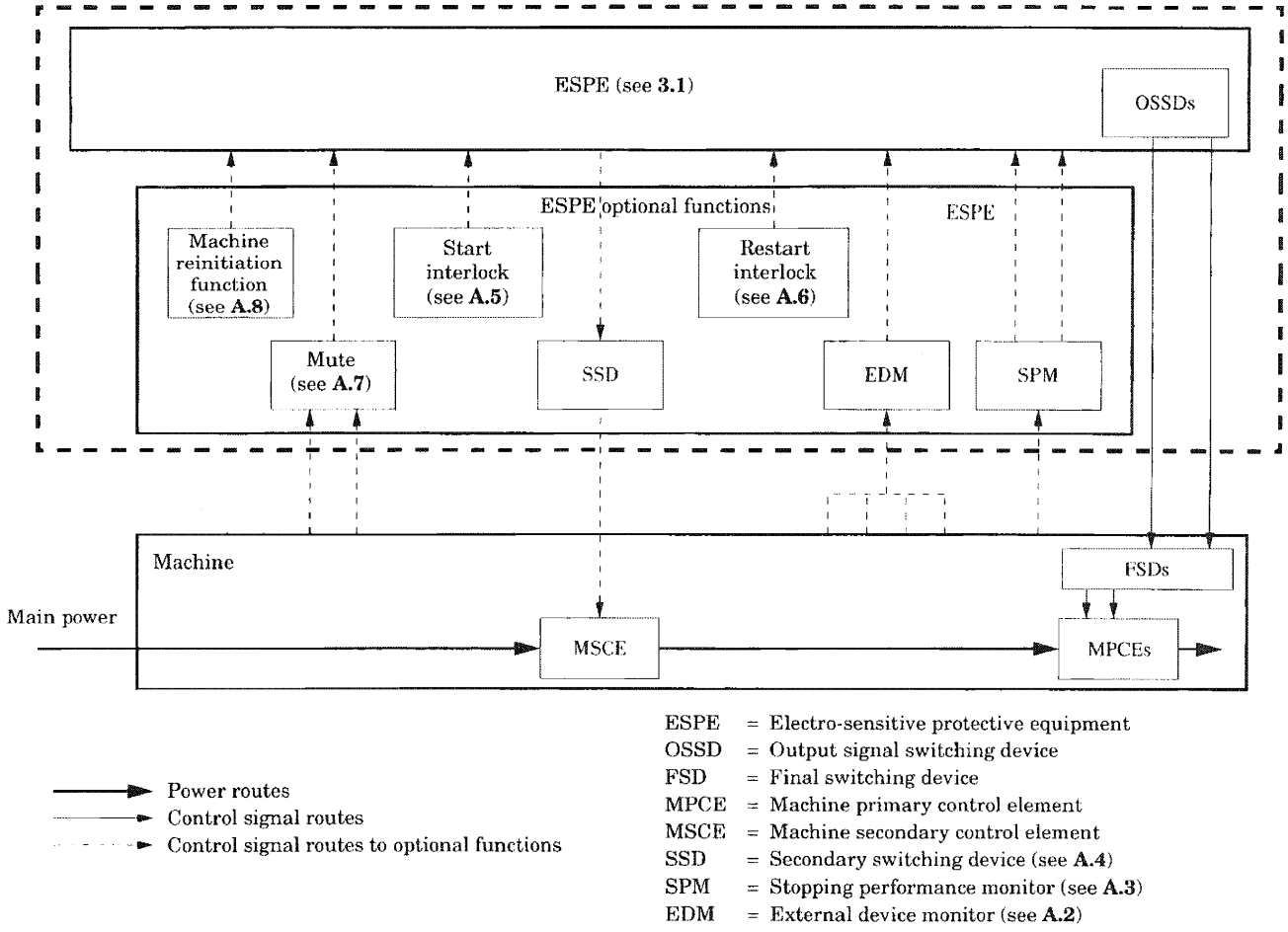

Figure A.1 Schematic example for the interfacing of a type 4 ESPE to a machine

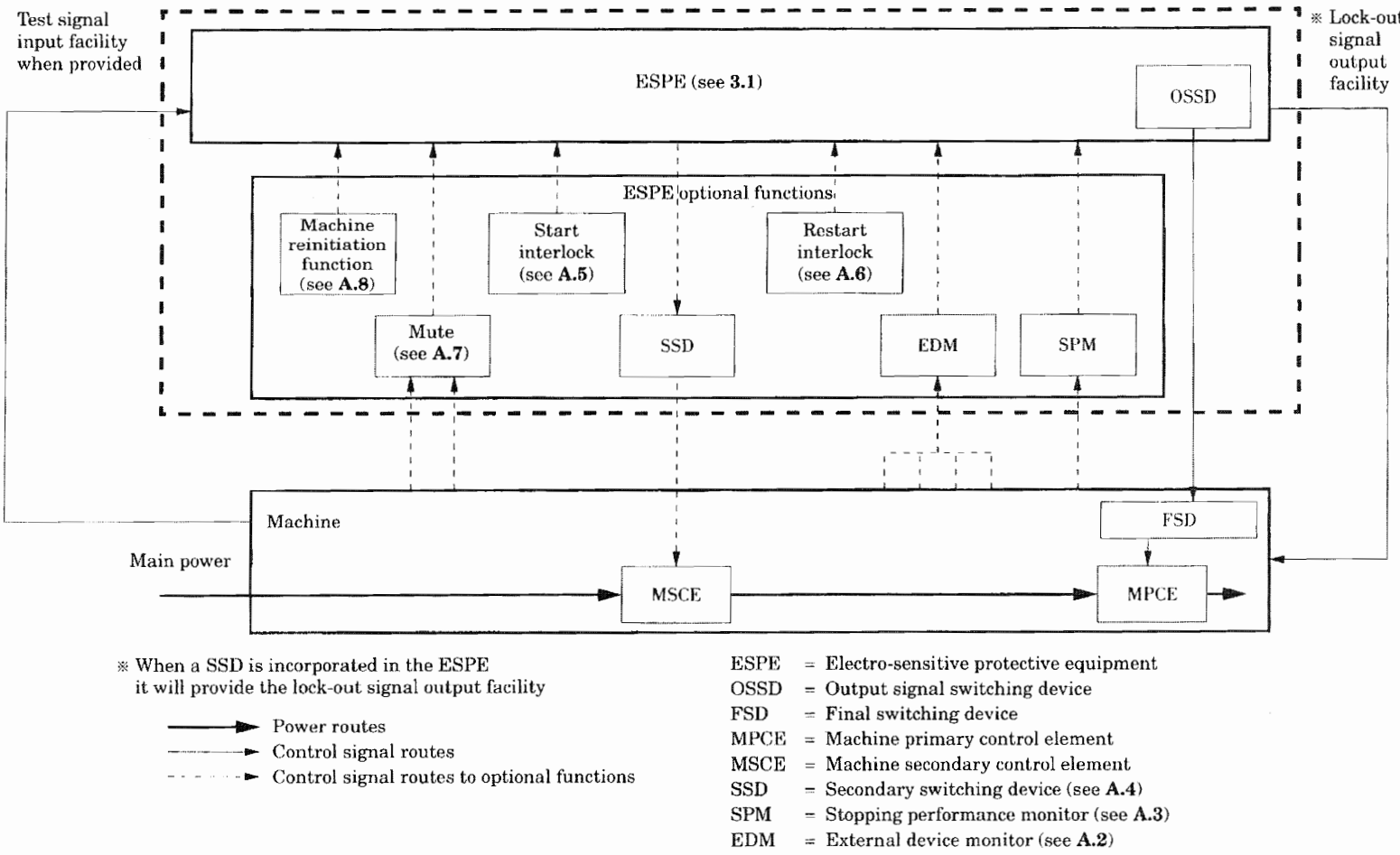

Figure A.2 Schematic example for the interfacing of a type 2 ESPE to a machine

Annex B (normative)

Catalogue of single faults affecting the electrical equipment of the ESPE, to be applied as specified in 5.3

B.1 Conductors and connectors

B.1.1 Conductors/cables

Faults considered	Exclusions
Short circuit between any two conductors	Conductors of a type 2 ESPE which are permanently connected (e.g. not using plug/socket combinations) and which are protected against external damage by, for example, cable ducting, armouring
	Conductors in separate multicore cables
Open circuit of any conductor	None
Short circuit between any conductor and an exposed conductive part or the protective conductor	None
Short circuit between any conductor and a live part	Conductors which are supported and/or terminated by multiconductor termination assemblies so as to prevent the fault occurring from, for example, mechanical failure near a termination point

B.1.2 Printed circuits and printed circuit assemblies

Faults considered	Exclusions
Short circuit between two adjacent conductors	Where: — the base material is according to **JIS*** and the creepage distances and clearances are dimensioned to at least **JIS C 8480**, annex 2 with pollution degree 2/installation category III; and — the assembled board is mounted in an enclosure giving a degree of protection to at least IP54 and the printed side(s) are coated with an ageing-resistant varnish or protective layer covering all conductor paths
Open circuit of any conductor path	None

JIS*: See **C 6482**, **C 6484**, **C 6485**, **C 6486**, **C 6488**, **C 6489**, **C 6490**, **C 6492**, **C 6493**, **C 6494**.

B.1.3 Terminal blocks

Faults considered	Exclusions
Short circuit between adjacent terminals	Where the terminals used are in accordance with a relevant **JIS** Standard and the requirements of **14.1.1** and **14.1.2** of **JIS B 9960-1** are satisfied
Open circuit of individual terminals	None

B.1.4 Multi-pin connectors (e.g. plug and socket for cable, relay, IC)

Faults considered	Exclusions
Short circuit between any two adjacent pins	Adjacent pins satisfying **B.1.2**
Interchanged or incorrectly inserted connector when not prevented by mechanical means	None
Open circuit on individual connector pin	None

B.2 Switches

B.2.1 Electro-mechanical position switches, manually operated switches and push-buttons (e.g. reset actuator, dip switch)

Faults considered	Exclusions
Contact pairs will not close	None
Contact pairs will not open	None
Short circuit between adjacent contacts insulated from each other	Only for type 2 ESPE where the switch used is in accordance with **JIS C 8201** and conductive parts which become loose cannot bridge the insulation between contacts
Simultaneous short circuit between three terminals of change-over contacts	Only for type 2 ESPE where the switch used is in accordance with **JIS C 8201** and conductive parts which become loose cannot bridge the insulation between contacts
Note: See also note to **B.2.2**	

B.2.2 Electro-mechanical devices (e.g. relay, contactor)

Faults considered	Exclusions
Does not de-energize (all contacts remain in energized position e.g. due to mechanical fault)	None
Does not energize (all contacts remain in de-energized position e.g. due to mechanical fault, open circuit of coil)	None
Individual contact not opening	None (see note)
Individual contact not closing	None (see note)
Simultaneous short circuit between the three terminals of a change-over contact	Only for type 2 ESPE where the creepage and clearance distances are dimensioned to at least **JIS C 8480**, annex 2 with pollution degree 2/installation category III and conductive parts which become loose cannot bridge the insulation between contacts
Short circuit between contact circuits, and between contacts and coil terminals	Only for type 2 ESPE where the creepage and clearance distances are dimensioned to at least **JIS C 8480**, annex 2 with pollution degree 2/installation category III and conductive parts which become loose cannot bridge the insulation between contacts and between contacts and the coil
Note: When relays/contactors with mechanically-linked contacts are used, the non-opening of a contact can be detected by monitoring the position of another contact in the assembly. Requirements for these assemblies are under consideration.	

B.3 Discrete electrical components

B.3.1 Transformers

Faults considered	Exclusions
Open circuit of individual winding	None
Short circuit between windings	Where the windings are separated according to **JIS C 9742**

B.3.2 Chokes

Faults considered	Exclusions
Open circuit	None
Short circuit	Where choke coil is single-layered, enamelled or potted, and with axial wire connections and axial mounting
Changing value: $0.5\ L_N < L < 2\ L_N$ where L_N is the nominal value of inductance	None

B.3.3 Resistors

Faults considered	Exclusions
Open circuit	None
Short circuit	Where the resistor is of the film type, or the wire-wound type with protection to prevent unwinding of the wire in the event of breakage, with axial wire connections, axial mounted and varnished No exclusion for resistors used in surface-mounting technology
Changing value: $0.5\ R_N < R < 2\ R_N$ where R_N is the nominal value of resistance	None

B.3.4 Resistor networks

Faults considered	Exclusions
Open circuit of individual resistor	None
Short circuit between any two connections	None
Changing value of individual resistor: $0.5\ R_N < R < 2\ R_N$ where R_N is the nominal value of resistance	None

B.3.5 Potentiometers

Faults considered	Exclusions
Open circuit of each individual connection	None
Simultaneous short circuit between all connections	None
Changing value between any two connections: $0.5\ R_P < R < 2\ R_P$ where R_P is the nominal value	None

B.3.6 Capacitors, fixed or adjustable

Faults considered	Exclusions
Open circuit	None
Short circuit	None, even with self-healing capacitors
Changing value: $0.5\ C_N < C < 2\ C_N$ + tolerance where C_N is the nominal value or set value	None

B.4 Solid-state electrical components

B.4.1 Discrete semi-conductors [e.g. diode, transistor, triac, voltage regulator, phototransistor and light-emitting diode (LED)]

Faults considered	Exclusions
Open circuit of any connection	None
Short circuit between any two connections	None
Short circuit between all connections	None
Changing electrical characteristics resulting in a safety-related output signal which is outside either the upper or lower limits of the defined signal range by 25 % of that range (see also **3.3**)	None

B.4.2 Optocouplers

Faults considered	Exclusions
Open circuit of individual connections	None
Short circuit between any two connections: — input connections (transmitter) — output connections (receiver) — between input and output	 None None Components having an impulse voltage withstand capability according to table 1 of **JIS C 8480**, annex 2, over-voltage category III
Changing electrical characteristics resulting in a safety-related output signal which is outside either the upper or the lower limit of the defined signal range by 25 % of that range (see also **3.3**)	None

B.4.3 Integrated circuits, simple

Faults considered	Exclusions
Open circuit for each individual connection	None
Short circuit between any two connections	None
Persistent "0" or "1" signal at all inputs and outputs, either individually or simultaneously (i.e. short-circuit to negative or positive rails with isolated input or disconnected output)	None
Parasitic oscillation of outputs NOTE: The choice of test frequency and the pulse duty factor is dependent on the switching technology and the external circuitry. When testing, the driving stages in question are disconnected	Type 2 ESPE where analysis indicates that it is not safety-related
Changing electrical characteristics resulting in a safety-related output signal which is outside either the upper or lower limit of the defined signal range by 25 % of that range (see also **3.3**)	None

B.4.4 Integrated circuits, complex or programmable

Faults considered	Exclusions
Defect in part or all of the function (see also **4.2.10** and **4.2.11**). The defect may: — be static — change the logic — be dependent on bit sequences	None
Undetected failure in the hardware that goes unnoticed because of the complexity of integrated circuit (see also **4.2.10** and **4.2.11**)	None
Defects in the storage and processing components not revealed by the complete execution of the program	None
All in **B.4.3**	See **B.4.3**

B.5 Motors

Faults considered	Exclusions
Motor stopped	None
Speed above normal	None
Speed below normal	None

Annex 1 (informative)

Comparison table between JIS and corresponding International Standard

JIS B 9704-1 : 2000 *Safety of machinery—Electro-sensitive protective equipment—Part 1 : General requirements and tests*			**IEC 61496-1** : 1997 *Safety of machinery—Electro-sensitive protective equipment—Part 1 : General requirements and tests*				
(I) Requirements in **JIS**		(II) International Standard number	(III) Requirements in International Standard		(IV) Classification and details of technical deviation between **JIS** and the International Standard by clause Location of deviation: Indication method:		(V) Justification for the technical deviation and future measures
Clause	Content		Clause	Content	Classification by clause	Detail of technical deviation	
1 Scope	Specifications of general requirements for the design, construction and testing of electro-sensitive protective equipment (ESPE) for the safeguarding of machinery	**IEC 61496-1**	Identical with **JIS**.	Identical with **JIS**.	IDT	—	
2 Normative references	Normative references of **JIS** consist of 15 standards (translation) and **JIS B 9960-1** : 1999, and **IEC**, of **IEC 60050** International Electrotechnical Vocabulary (IEV) and 2 informative references.	**IEC 61496-1**	Identical with **JIS**.	Different from **JIS**.	MOD/ addition	Among the normative references, **JIS C 9742** : 2000 is not based on any International Standards.	**JIS C 9742** : 2000 specifies isolating transformers based on Electrical Appliance and Material Control Law.
3 Definitions	29 terms are defined.	**IEC 61496-1**	Identical with **JIS**.	Identical with **JIS**.	IDT	—	

(I) Requirements in **JIS**		(II) International Standard number	(III) Requirements in International Standard		(IV) Classification and details of technical deviation between **JIS** and the International Standard by clause Location of deviation: Indication method:		(V) Justification for the technical deviation and future measures
Clause	Content		Clause	Content	Classification by clause	Detail of technical deviation	
4 Functional, design and environmental requirements	Functional, design and environmental requirements for ESPE are specified.	**IEC 61496-1**	Identical with **JIS**.	Different from **JIS**.	MOD/ addition	Isolating transformers based on **JIS C 9742** : 2000 are specified in **4.2.1**. Provision in **4.2.3.1** admits components which conform to **JIS** but not to any International Standards.	Molded case circuit breakers and residual current operated circuit breakers specified in **JIS C 8370** : 1996 and **JIS C 8371** : 1992, respectively are added to **4.2.3.1**. **JIS** intends to achieve future conformance to International Standards.
5 Testing	Conditions, measurement accuracy and documentation of test results for tests such as type tests, functional tests, performance tests under fault conditions and environmental tests are specified.	**IEC 61496-1**	Identical with **JIS**.	Identical with **JIS**.	IDT	—	
6 Marking for identification and for safe use	Information to be marked, location, type of marking are specified.	**IEC 61496-1**	Identical with **JIS**.	Identical with **JIS**.	IDT	—	
7 Accompanying documents	Specifications of documentation provided by the supplier of the ESPE, which contains information required for the installation, use and subsequent disposal of the ESPE	**IEC 61496-1**	Identical with **JIS**.	Identical with **JIS**.	IDT	—	

(I) Requirements in **JIS**		(II) International Standard number	(III) Requirements in International Standard		(IV) Classification and details of technical deviation between **JIS** and the International Standard by clause Location of deviation: Indication method:		(V) Justification for the technical deviation and future measures
Clause	Content		Clause	Content	Classification by clause	Detail of technical deviation	
Annex A (normative)	Specifications of the requirements of optional functions of the ESPE	**IEC 61496-1**	Identical with **JIS**.	Identical with **JIS**.	IDT	—	
Annex B (normative)	Specifications of single faults affecting the electrical equipment of the ESPE	**IEC 61496-1**	Identical with **JIS**.	Identical with **JIS**.	IDT	—	

Designated degree of correspondence between **JIS** and International Standard: MOD

Remarks 1 Symbols in sub-columns of (IV) in the above table indicate as follows:

"IDT" and "—": Identical in technical contents.

"MOD/addition": Adds specification item(s) or content(s) not included in International Standard.

Errata for JIS (English edition) are printed in *Standardization Journal*, published monthly by the Japanese Standards Association, and also provided to subscribers of JIS (English edition) in *Monthly Information*.

Errata will be provided upon request, please contact:

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